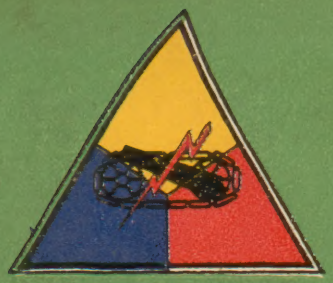


ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 6 - VISION IN TANKS

Second Partial Report

On

Sub-Project No. 6-2, Study of Characteristics and Limitations of Present Visual Devices in Tanks

Sub-Project No. 6-4, Study of Means for Improving Sighting Telescopes

PLACEMENT AND MOUNTING OF SIGHTS IN TANKS

Project No. 6-2, 6-4 INFORMATION COPY 9 June 1943

ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Projects No. 6-2, 6-4
413.74-1 GNOML 9 June 1943

PLACEMENT AND MOUNTING OF SIGHTS IN TANKS

1. PROJECT: No. 6 - Vision in Tanks; Second Partial Report on Subprojects No. 6-2 - Study of Characteristics and Limitations of Present Visual Devices in Tanks; and 6-4 - Study of Means for Improving Sighting Telescopes.

a. Authority: Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose: To improve fire control in armored vehicles by better placement and mounting of sights.

2. DISCUSSION:

a. Fire control in tanks now employs both the periscopic and the coaxial sights. The periscope provides general vision and a low power (1.44x) sight for proximate and moving fire, whereas the coaxial telescopic sight, of higher power (3x) is employed for shooting at distant targets. It is essential that both sights be so located that the gunner can shift quickly from one to the other.

b. A dual periscopic sight (T8) has been designed to replace the present gunner's periscope. T8 will provide, in addition to general vision, a unit-power sight for proximate shooting and shooting while moving, and a 6 power sight having the optimal properties required for shooting at greater distance. The 3 power coaxial telescope will then be a reserve or compromise sight to serve all purposes, in the event of loss of the periscope.

c. Both the present and the new periscope have the same requirements with respect to precision, rigidity of mounting and placement for convenient access. Alignment of all sights must be securely maintained.

d. The placement of the two sight units so as to insure ready access to either one makes certain demands upon turret design. For proper balance and operation of the 75 mm and the smaller guns, the gun trunnions can be placed well within the turret ring and, as a consequence, excellent placement of sights with respect to the gunner is possible. In order to

balance the 76 mm and the larger guns, however, and also provide space for loading, the gun trunnions must be moved forward and the problem of fitting the sights and gunner into favorable positions becomes more difficult. The practical limit in this respect is believed to be reached with the axis of gun trunnions 36" from the center of a turret of the present size (about 68" inside diameter).

e. For guns larger than the 76 mm, satisfactory placing of the straight sight is extremely difficult if not impossible of attainment and some alternative plan of fire control should be adopted. One solution (used by the Germans) is to employ an articulated coaxial sight, which is inferior in optical quality to a straight sight. Another solution, believed to be superior, is to use a prismatic sight with proper linkage, off-set through the side armor.

f. In all plans for fire control, accurate and reliable linkage of sight to gun is essential. There are no insurmountable mechanical difficulties involved in the design and construction of a linkage system that will retain a precision of action in keeping with the accuracy of the gun and sights.

g. Requirements for the placement and mounting of sights are presented in Appendix I. Considerations underlying these specifications are given in Appendix II.

3. CONCLUSIONS:

a. In no tank examined to date, either in mock-up, as a pilot model, or production vehicle, have entirely satisfactory provisions been made for fire control by periscope and coaxial telescope.

b. Improvements in arrangement and mounting can be readily accomplished.

c. With present ring diameter (68" i.d.) and general layout and design of turret, the practical limit of use of the present system of fire control (using a non-articulated coaxial telescope and periscope) is reached when the axis of the gun trunnions has been pushed forward about 36" from the center of the turret ring.

d. For guns larger than 76 mm, with the axis of the trunnions more than 36" from the center of the turret another plan for fire control which does not make use of the straight coaxial telescope should be considered.

e. More rugged and accurate mounting and linkage of sights must be developed.

f. If the most effective fire control is to be obtained, requirements for proper placement of sights, controls, and positioning of gunner must receive primary consideration in the design of the turret, even at the expense of other desirable features.

4. RECOMMENDATIONS:

a. That, in the design of all turrets in which fire control by periscope and coaxial sight is employed, the spatial arrangements be such that -

(1) Ready access to and effective joint use of the two sights is insured.

(2) The coaxial telescope can be used in a single seat position without unduly tiring the gunner, at least within the commonly occurring range of use from 11° depression to 10° elevation of the gun.

(3) No interference occurs to prevent the use of both sights by men of either eye dominance.

(4) The controls be so located that free movements and natural coordination are possible for at least the commonly occurring positions of the gunner.

b. That the mounting of the coaxial telescope be of such ruggedness that loss of alignment will not exceed 1/4 mil under loading tests in excess of common-use requirements.

c. That bore-sighting adjustments be:

(1) Smooth and without detents.

(2) Independent in elevation and in azimuth.

(3) Capable of being locked without disturbing the alignment.

d. That in new turret designs, the opening in the top armor for the periscope be increased in order to permit adequate precision and rigidity in the mounting of the periscope.

e. That effective lever lengths of the linkage be increased to the point where common machine practice will insure an accuracy of alignment within 1/4 mil.

f. That the ruggedness of the combined linkage and periscope mounting be such that alignment within 1/4 mil will be maintained under loading tests in excess of common-use requirements.

g. That all clearances in the mounting of the periscope be increased to avoid binding by grit, sand and dust and that the space be filled with suitable material to seal against rain, dust and "blow by".

h. That the detailed specifications in Appendix I be regarded as the limiting minimum requirements essential to the accomplishment of these recommendations.

Note: Many of the limiting dimensions given are not only critical in themselves but are closely interdependent so that successful accomplishment of placement requires that consideration be given to these specifications as a whole.

APPROVED Willard Machle
WILLARD MACHLE
Colonel, Medical Corps
Commanding

Submitted by:

Major F. S. Brackett, Sn C

3 Inclosures
#1 - Appendix I
#2 - Appendix II
#3 - Fig. 1

APPENDIX I

REQUIREMENTS:

Effective fire control requires the proper relation of the gunner's position to the sights and his controls. The following dimensional requirements set the limits beyond which one cannot go without serious loss of effectiveness in the direct laying of the gun.

1. Location of coaxial telescopic sight.

a. Horizontal distance from eye position (gun level) to axis of gun trunnions not to exceed 20" (good, 13"). Dimension A in Fig. 1.

b. Lateral distance from eye position to recoil guard (or other interference on gun) to be 5 inches or more (good, 10"). Dimension B in Fig. 1.

c. Recoil guard to be extended parallel to the gun for at least 13" behind the eye position of the coaxial telescope, for shoulder room. Dimension E in Fig. 1.

d. Lateral distance from eye position to edge of periscope housing, linkage or other nearest interference to be from 5 to 6 inches. Dimension C in Fig. 1.

e. At full depression, vertical distance from eye position to roof to be not less than 6-1/2". Dimension D in Fig. 1.*

2. Location of periscope.

a. Horizontal distance from periscope eye position (gun level) to the axis of gun trunnion to be 1-1/2" (± 1/2") greater than the distance from the eye position of coaxial telescope to the trunnion axis (Note: This brings the center of the periscope in the plane of the telescope eyepiece). (Fig. 1)

b. Vertical distance from horizontal plane at eye position to the roof above to be not less than 5" at the eye position (Dimension F in Fig. 1) and not less than 6-1/2" at a point 5" behind the eye position (Dimension F' in Fig. 1).*

c. Slope of turret roof in front of periscope to be at least 17° downward to insure full field of view with gun in maximum depression.

---

* This assumes a crash helmet not to exceed 3/4" at top.

Inch. #1

3. Location of controls.

a. For optimum use, horizontal distance from the center of elevating and traverse controls to the vertical plane of the eye position to be 5" (± 1") when the controls are approximately 25" from the roof*. Dimension G in Fig. 1.

b. Vertical clearance for knees should be at least 25" from floor.

4. Placement of gunner.

a. Plane of back of seat to the plane of the eye* to be adjustable from 15" to 19". Dimension I in Fig. 1.

b. Height of seat (cushion depressed) to turret roof to be adjustable between 36" and 44" with 1" increments of adjustment from 36" to 39". (Note: Provisions for further seat adjustment between 39" and 44", for use of the telescope with gun in extreme elevation, requires further study.)

5. Mounting of coaxial telescope.

a. Mounting to be constructed so that bore-sighting adjustment is:

(1) Smooth, without detents.

(2) Independent in elevation and azimuth.

(3) Capable of being locked without disturbing alignment.

b. Telescope mounting to be sufficiently rugged to withstand 200 pounds pressure at any point on the mount and in any direction without loss of alignment of more than 1/4 mil. in respect to bore of the gun.

c. Outside opening for coaxial sight to be provided with a protective armor flap to serve as a dirt-tight cover when closed and a sun shade when open, the actuating mechanism to be positive and dependable.

6. Construction and mounting of periscope and linkage.

a. Provide an opening through the armor 4" x 11" (rounded ends) and an outside flange seat 6" x 13" (rounded ends).

b. Mounting to be constructed to accommodate a periscope 2-1/4" x 7".

c. Precision of mounting to be such as to maintain parallelism with bore of gun within 1/4 mil with movement of gun into any position.

d. Effective length of lever arm in linkage system to be not less than 12". Preloaded, medium duty ball-races of highest precision to be press-fitted into all joints of the linkage system.

---

* Eye at coaxial telescope with gun level.

Encl #1

e. Periscope mounting and linkage system to be sufficiently rugged to withstand a pressure of 200 pounds at any point on the mount and in any direction without loss of alignment of more than 1/4 mil.

f. All clearances in periscope mounting to be sufficient to avoid binding by sand and spaces to be filled by wipers of soft material to seal against dust, rain and "blow by".

Amd. #1

APPENDIX II

DISCUSSION

1. Coaxial mounting of sights.

a. The mounting of a sight coaxially with the gun has the great advantage that it may be made an integral part of the gun mount, and hence, there should be no loss of alignment with the weapon. This advantage may be lost, however, when provisions are made for ready interchange and adjustment of alignment of sights since the mechanical difficulties involved in providing the requisite movements for adjustment in elevation and azimuth are practically as great as the problem of obtaining adequate linkage.

b. Favorable placement of a coaxial sight is obtained when the eyepiece is close to the gun trunnion axis so that there is little excursion during change of elevation. As the distance from eye to trunnion axis is increased, the excursion also increases, forcing the gunner into awkward positions in using the telescope, thus limiting the possible range over which the instrument can be employed without changing seat position. The limiting effect of increasing the eye to trunnion distance upon the available range of gun elevation in relation to gunner's position, is shown in Table 1. This table is based upon the most favorable selection of seat position and vertical displacement of the sight with respect to gun trunnions.

Table 1

Distance - Eye to Trunnion	Maximum Angle of Available Depression	Maximum angle of Elevation for which the gunners position is			
		Comfortable	Tiring	Cramped	Contorted
12"	14°	16°	20°	28°	
13"	13°	15°	19°	25°	30°
14"	12°	14°	18°	23°	28°
16"	12°	11°	14°	18°	23°
18"	12°	8°	12°	15°	19°
20"	11°	7°	10°	13°	16°
23"	10°	6°	9°	11°	13°
26"	10°	4°	6°	8°	10°

c. The required length of the coaxial sight is not determined by optical demands but is fixed by the distance from the eye of the gunner to the perforation in the frontal armor. The location of this perforation is dictated by ballistic considerations. To obtain a minimum opening, the entrance pupil of the sight must be in the outer face of the armor and the armor must move with the gun, hence a broad gun shield. The least distance from the opening in the shield to the vertical plane of the trunnion axis is likely to be about 8". The gunner's eye must be brought as close as possible to the axis of the gun trunnions, in order to minimize the eyepiece excursion. Placing the gunner as far forward as possible in the turret, his eye is some 16" forward of the center of the turret. Thus, if the gun trunnion axis is 28" from the center, as in the M4, the eye to trunnion distance would be only 12". In order to provide room for loading longer shells and to balance a long gun such as the 76 mm, the trunnion axis must be moved farther forward. With the trunnion axis 36" from the center, the eye to trunnion distance becomes 20", which we believe to be a maximum for even acceptable use. (See Table 1.) This leads to a sight 19" to 27" long, depending on the placement of the trunnion axis.

d. Optics suitable for coaxial sight.

An overall length of 19" or more is suitable for a straight tube sight of the lens erecting type but is too great for a simple prismatic type. The straight tube sight with erecting lens is inferior to the shorter prismatic sight in breadth and flatness of field, light transmission and freedom from veiling haze.

It is, however, mechanically simpler to construct and mount. If the position of gunner and the eye-to-trunnion distance can be brought within the limits given above, the straight tube telescope is a desirable choice for one of the sight units.

e. The articulated sight.

When the eye to trunnion distance exceeds 20", the excursion of eyepiece becomes excessive and some other solution must be found. For this situation the Germans have employed a broken or jointed sight. The forward portion, including objective and reticule, is mounted coaxially with the gun but through movement at the joint, the eyepiece remains practically stationary. While this eliminates the problem of excessive excursion it requires a complex mechanical arrangement and a loss of optical quality as compared with the straight tube sight. An alternative is to go to linked sights.

2. Linked sights.

a. The best optically quality is obtained in a short prismatic sight, which is very flexible in form. The light path is naturally offset,

as in binoculars, and the offset distance can be varied from 1" to 9". This type of sight readily lends itself to favorable mounting from the standpoint of ballistics. It can be designed to go up through the turret roof or out through the side armor.

The T8 Dual Periscope with 6 power magnification now under construction, is of this type and a four power prismatic system designed for use through the side armor has been mocked-up by the Armored Force Medical Research Laboratory.

b. Since a short offset sight must be mounted with its axis of rotation parallel to but displaced from the gun trunnion axis, a system of linkage is required. While this introduces further mechanical parts, there is no fundamental difficulty in producing a dependable alignment with the gun bore. The poor performance of linked sights has resulted, for the most part, from failure to follow the simple engineering requirements of the problem.

c. A linkage system of the desired precision must combine an adequate lever length with good bearings. The shorter the lever the more precise must be the bearings and the more rigid the links; thus, to insure an accuracy of 1/4 mil, a 4" lever requires bearings accurate to $\frac{2.5}{10,000}$" and negligible flexure; whereas, with a 16" lever the bearings must be accurate to only $\frac{1}{1,000}$" which is the tolerance obtained in ordinary machine practice.

These obvious requirements have not been met in any design so far developed. The use of a long lever arm makes certain demands upon the basic layout of the turret that have not been considered and the periscope will have to be actuated by a heavy shaft in order to place the linkage where it will not interfere with the gunner. In the alternative use of a short lever preloaded bearings of the highest precision must be press-fitted into the units and the link arms must be of great strength to prevent flexure. This is an essential improvement if the present linkage design is to be employed.

3. Minimum clearance in placement of sights.

a. The spatial arrangement of the sights in relation to the gun, gunner and turret is shown in Fig. 1. The drawing illustrates the limiting case where the gun trunnion axis is placed as far forward as possible in order to mount the largest gun that is practicable with the present type of fire control.

b. Here the axis of the gun trunnions is 36" from the center of the turret (Dimension K in Fig. 1); that is, 2" outside the inner face of the ring (diameter 68"). The gunner is placed so far forward that special care must be taken to avoid knee interference - probably necessitating the

relocation of the power-driven oil pump and accessories. The eye position of the coaxial telescope (with the gun level) is 16" in front of turret center (J in Fig. 1) and 20" behind the axis of the gun trunnions.

c. The recoil guard should be carried back parallel to the gun for 13" behind the eye position as shown in the drawing in order to insure reasonable shoulder room. If the gunners shoulder comes against the bulge in the guard, a position, which is not too convenient at best, becomes seriously cramped.

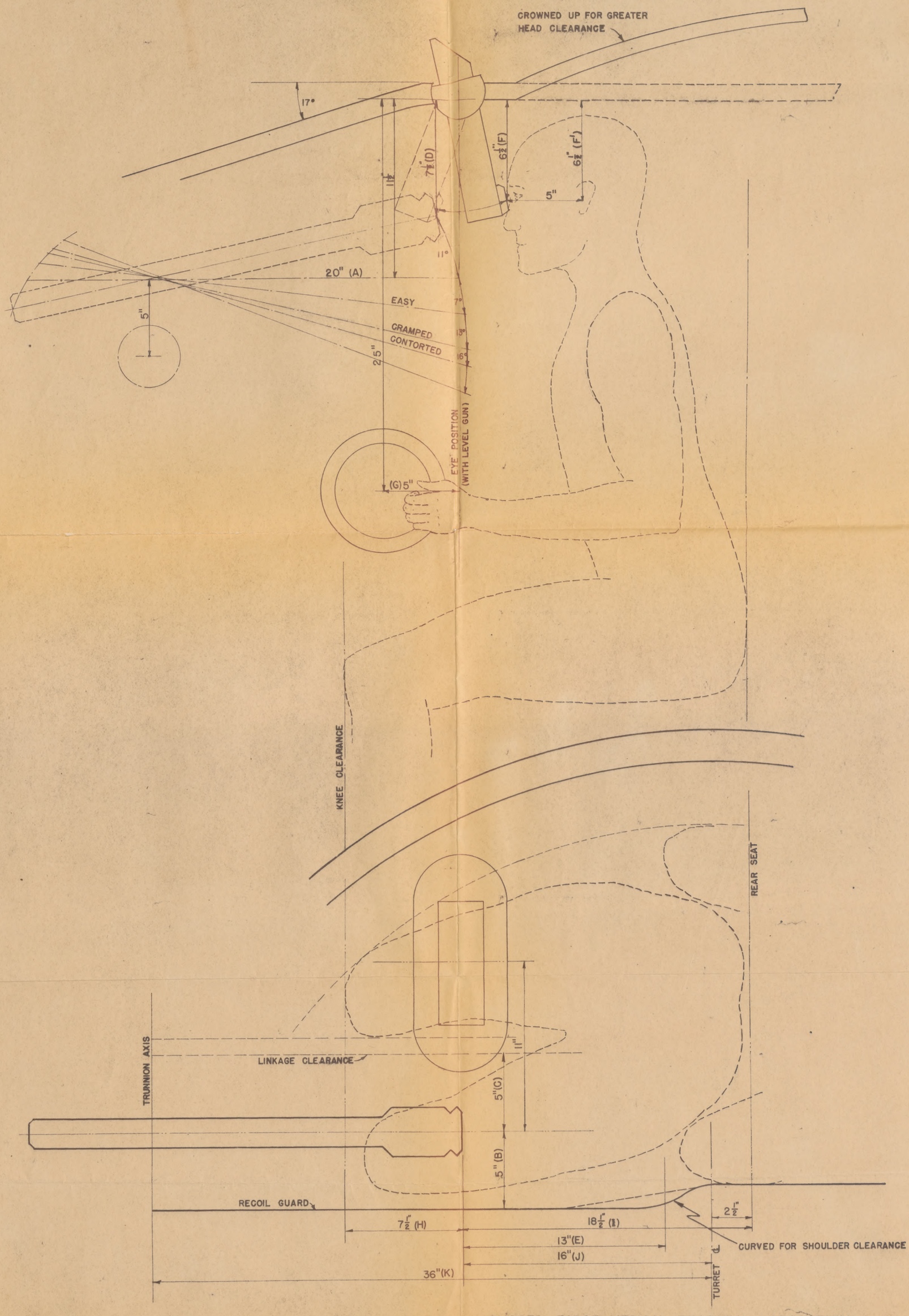
d. The gunner's seat must be adjustable vertically to allow for the normal variation in sitting height of the gunner. It must also be capable of further lowering in order to reach the telescope eye position when the gun is in extreme elevation. Only the most commonly used elevations can be reached from a single optimum seat position.

e. The arrangement of sights, gun trunnions and gunner shown in the drawing is far from optimum but represents the practical limit which will permit effective use of the equipment. If sufficient room is not allowed to place the gunner as far forward in the turret as recommended, then the axis of the gun trunnions must be drawn back to attain as satisfactory placement of sights.

Encl #2

FIG. I.

SPATIAL ARRANGEMENT AND MINIMUM CLEARANCES IN THE PLACEMENT AND MOUNTING OF THE COAXIAL AND PERISCOPIC SIGHT



ARMORED FORCE MEDICAL RESEARCH LABORATORY

MAJOR F. S. BRACKETT JUNE 2, 1943

FIG. I.